



Chapter 4

Considerations for a Solution

Table of Contents

Objectives and Design Criteria	4-4
Describing Objectives	4-4
Defining Design Criteria	4-4
Risk and Cost Assessment	4-5
Assessing Risk Associated with Bank Protection	4-6
Relating Risk to Hydrologic Probability	4-6
Habitats Commonly Affected by Bank Protection	4-7
Spawning	4-7
Cover	4-8
Habitat Complexity and Diversity	4-8
Riparian Function	4-8
Flood Refuge	4-9
Sediment and Debris Sources	4-9
Off-Channel Rearing Habitat	4-9
Duration and Extent of Impacts	4-10
Construction-Activity Impacts	4-10
Direct Habitat Loss	4-10
Channel Response Impacts: On Site, Off Site	4-10
Lost-Opportunity Impacts	4-11
Impacts of Perceived Protection	4-15
Mitigation	4-15
Legal and Policy Basis of Mitigation	4-15
Mitigation Concepts for No Loss-of-Habitat Functions	4-17

Integrating Mitigation into Bank-Protection Projects.....	4-22
Emergency Bank Protection	4-26
What Constitutes an Emergency?	4-26
Designing and Installing Bank Protection	
During Emergency Conditions	4-27
Emergency Bank-Protection Techniques	4-27
Follow-Up Work After Installation	
of Emergency Bank Protection	4-28
Maintenance, Adaptive Management and Monitoring	4-28
References	4-29

Chapter 4

Considerations for a Solution

This chapter links the building blocks of site and reach assessments described in Chapters 2, *Site Assessment* and Chapter 3, *Reach Assessment* with the engineering considerations involved in risk assessment and mitigation procedures when dealing with lost habitat (Chapter 5, *Identify and Select Solutions*). The information contained in this chapter will help establish project* objectives and design criteria, which include consideration of habitat mitigation, risk, the emergency nature of the work and project management. Developing design criteria involves integrating various project elements, including technical performance, cost, acceptable risk, mitigation requirements and maintenance needs.

* In this context, the term “project” refers to the actual protection treatment used, not just the effort to construct or install the treatment.



OBJECTIVES AND DESIGN CRITERIA

Integrated Streambank Protection is a strategic approach to managing erosion on streambanks and channels that protects lives, properties and structures while also protecting or restoring a stream's ecological value. It may involve structural or nonstructural solutions, or both, integrated with ecological functions. It may also result in solutions that allow continued erosion. The desire to stabilize a streambank may be driven by the need to protect a physical structure or to protect land from being consumed through bank erosion or instability. A number of objectives may be imposed on such a project, some of which may even be in conflict with each other.

Describing Objectives

Selecting an appropriate bank treatment requires identifying all the objectives associated with the project, including ecological functions associated with the site. Objectives are usually described qualitatively. For example, a project might have an objective such as: "to stabilize the streambank for 500 feet upstream of the bridge at Highway 50 so the bridge isn't undermined," or "to stop the streambank erosion that is threatening private residences."

Objectives should be stated in terms of the desired outcome to be achieved. Do not include methods in the stated objectives. Doing so may create unintended problems, such as causing certain solution options to be selected or rejected prematurely, and risks may not be accurately characterized or evaluated. For example, although erosion caused by a large flood appears to threaten property, focusing on the erosion risk may place the property in further danger if the real risk (and solution) has to do with the probability of large flood events in the future. Rather than stating the objective as "stabilize the streambank to protect property and lives," state the objective in terms of outcomes: "take action to minimize the risk erosion poses to property and lives." Doing so enables all solution options to be considered, selected and/or rejected based on their individual potential for success. Folding the concepts of *Integrated*

Streambank Protection into the picture, the objectives might also include something like, "... while protecting the aquatic productive capacity of the site." The objective might even include other factors such as protecting recreational or scenic values.

Defining Design Criteria

Design criteria are specific, measurable attributes of project components developed to meet objectives. Put more simply, they describe how a successful outcome would function if the objective were met.

Design criteria are target standards or performance measures set for individual components of a design, providing numeric, allowable limits of performance and tolerance for bank-protection components and mitigation features. These performance measures relate to reversing, preventing or minimizing the mechanisms of failure described in Chapters 2 and Chapter 3, as well as achieving the proper function of mitigation features.

Design criteria are a key to establishing mutually understood expectations for the property owner, project sponsor, designer and regulatory agencies. They also form an agreed-upon, objective basis of evaluation to determine whether the fix was effective or not. While an objective might be stated in general terms, such as "minimize erosion" and "maximize stability during high flood events," design criteria are more specific; they describe what it means to meet the objective. For example, a set of design criteria for bank stabilization might include*:

- The bank-toe stabilization measures taken shall resist scour forces up to and including a 25-year discharge.
- The bank protection above the water level that occurs at the five-year discharge shall resist shear stresses of 0.5 pounds per square foot.

*the design-criteria examples listed in this chapter may or may not be appropriate for any given project. Specific criteria must be determined for each individual project.

Selecting an appropriate bank treatment requires identifying all the objectives associated with the project, including ecological functions associated with the site.



- Stabilization measures shall account for potential bed degradation of two feet in the event channel degradation continues.
- Bank-toe woody material shall resist buoyancy and shear forces up to and including those that occur during a 10-year recurrent flow.
- Shoots from grasses planted on the upper bank shall cover 80 percent of the ground surface at the end of the second year following project implementation.
- At least 80 percent of the woody plant material shall survive three years after placement.
- Scour pools created by each mitigation debris jam shall result in an average of at least 600 cubic feet of pool volume covered or within 10 feet of the major debris jam elements.

Design criteria are what make it possible to achieve the stated objective. They help the project participants describe what the objective means, figure out how to achieve the objective and measure whether or not the strategy to meet the objective succeeded. When applied in conjunction with design analysis, design criteria might answer questions such as:

- What type of bank-surface protection is appropriate, if any?
- How big should the toe foundation material be, and how deep should it be placed beneath the existing stream bed?
- What specific mitigation features will be required, and how secure must they be?
- What type of erosion-control fabric, if any, should be used on the upper bank, and how should it be installed?
- What trees and shrubs should be used for revegetation; how large should they be when planted, and how should they be cared for?

The number and focus of design criteria for any given project depend upon the scale and extent of the particular project itself. Simple, uncomplicated projects with little ecological effect may require only a few design criteria, whereas more complex or risky projects may require a

more extensive suite of criteria. Depending upon the problem to be solved, design criteria may take into account any number of components. For example:

- Vertical Stability: bed-material gradations and distribution, grade-control-structure rock size, structural dimensions and placement details.
- Lateral Stability: deformable or nondeformable bank, composition and character of bank toe (including depth, width and angle, upper-bank backfill or soil material and slope) and surface protection.
- Floodplain Surface Stability: time required to achieve vegetative stability and allowable shear forces on the floodplain surface.
- Aquatic Habitat: function, description, quantity, location and durability of various habitat types after initial construction and as affected by subsequent flood events.
- Revegetation Success: vegetation zones and landscape position, lower limit of vegetation, species composition, plant density and performance, irrigation needs, weed control and maintenance requirements.
- Constructability Considerations: construction time window and sequencing needs, dewatering methods and protection of fish, erosion- and sediment-control measures, staging areas for materials and equipment, heavy-equipment capabilities, access requirements and site restoration.

RISK AND COST ASSESSMENT

Assessing risk is a highly subjective yet critical process in evaluating bank erosion and considering management steps. Risk is the product of consequence and probability. A high-risk situation is one in which the probability and/or the consequence of failure is high. A lower-risk situation is when the probability of occurrence or the nature of the outcome is less severe. Determining the nature and degree of risk depends upon the point of view of those who have a stake in the outcome. For instance, weighing risks to habitat, property and safety against each other will likely result in differing conclusions, depending upon whether one is a property owner, a recreationist or a resource manager. Assessment should always weigh the risks of bank protection as well as the risks of bank erosion. Just as the nature of stream activity should be assessed in terms of site conditions and reach conditions (as discussed in Chapter 1, *Integrated Streambank Protection*), the nature of risks should also be considered within such a context.



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Site risks to consider in terms of both erosion and steps to correct erosion include impacts on:

- property and infrastructure,
- habitat, and
- public safety.

Reach risks to consider in terms of both erosion and steps to correct erosion include impacts on:

- channel stability, and
- habitat.

While some risks are difficult to quantify, due diligence in addressing all certain and potential financial and resource costs will only contribute to a more successful outcome in resolving the streambank or channel issue.

Cost considerations for both bank erosion and bank protection should include:

- repair of damage to property and infrastructure;
- relocation of at-risk facilities;
- compliance with legal requirements for habitat rehabilitation;
- restoration of the channel to prevent further habitat losses associated with a bank-stabilization project;
- design (including appropriate geomorphic and hydrologic analyses), construction and maintenance of the bank-protection treatment; and
- habitat mitigation for the duration of the impact, including any required monitoring and mitigation adjustments.

Assessing Risk Associated with Bank Protection

The selection of streambank treatment is often guided by the assessed risk of failure. The use of “soft” bank-protection techniques, such as revegetation, can be used if either the probability or consequence of continued bank failure is low. In their early stages, purely vegetative bank-protection techniques often provide less guarantee of

protection than more structural techniques. However, they can act as a buffer initially, and they provide secure protection once vegetation becomes established and bank strength is restored.

An eroding bank is not usually a risk to habitat. Erosion is a natural process that can recruit large woody debris and sediment necessary for a healthy stream and riparian ecosystem; but accelerated erosion, especially of fine-grained material, can be a risk to habitat by filling pools and contaminating spawning beds. Additionally, steps to stabilize streambanks can have a habitat-restoration value by restoring channel geometry.

Relating Risk to Hydrologic Probability

The selection of design criteria is guided by the risk of failure. Since the success or failure of bank stabilization is dependent on flood events, design criteria and risk are defined by the probability of occurrence of a flow of a given size. Some design criteria need to relate to a specific, limited time window. For example, revegetation might require five years of development before it succeeds in its objective of bank stabilization, and establishing measurements for the success of that treatment will need to take this into account. Other criteria may take into consideration longer return periods, depending upon the need. For example, a design might include a criterion such as, “vegetative bank protection shall resist erosion with 70-percent assurance during the first five years and 80-percent assurance over the next 50 years.”

Design criteria can be established that consider the erosive forces exerted during a flow of a particular magnitude, also referred to as the “design flow.” By using the probability of a flow occurring during a limited time frame, variable levels of risk can be considered. Design flow (that is, a flow of a defined level) is described by the likelihood of recurrence over time. A “100-year flood” is the flow that has a one-percent probability of occurring in any given year. Although such a flow could occur in two consecutive years, the statistical probability is one percent in any given year. The statistical probability of occurrence of a specific level of flood is typically related to an unlimited time frame. When the statistical probability of a specific flow happening within a limited time is calculated,



for example within the next ten years, the likelihood of recurrence is lower than it would be for an unlimited period and is calculated as:

$$P = 1 - (1 - 1/T)^N$$

where:

P = probability that a given flow will occur at least once during the next **N** years;

T = recurrence or return interval; and

N = specified number of years in time window.

In many cases, design criteria for the same project may relate to different design flows. For example, a bank toe of rock might be designed to withstand forces up to the 25-year flow, whereas surface protection of a floodplain against potential avulsion might be designed to the five-year flow. A reason for this difference might be the expectation that the immediate risk of avulsion is acceptable and natural vegetation growth on the floodplain will reduce the risk over time.

There are two approaches to determining appropriate design flow. The first is quite simple and involves selecting a suitable risk level based on probability. For example, a common standard for protecting infrastructure is to design for a one-percent-probability flow, recognizing that such a flow may actually occur in any year or sequence of years. However, application of that standard may be overly simplistic and inappropriate. Design standards for a project take into account the risk, cost and habitat implications associated with adhering to them.

The second method of determining appropriate design flow is an integrated and iterative approach, where methods, risk, mitigation, sequencing and costs are considered. Risk can be viewed in the context of limited and/or unlimited time frames. One can evaluate the forces at various flows, consider the methods required to provide stabilization at these flows, evaluate the costs and habitat mitigation requirements of the different levels of stabilization and choose a design flow that achieves the objectives of the project at the best value.

HABITATS COMMONLY AFFECTED BY BANK PROTECTION

This section explains various habitat characteristics and how bank-protection efforts might affect them. See Appendix G, *Biological Considerations* for a more complete description of habitats.

Spawning

Spawning habitat is created by the interaction of high flows with channel geometry, sediment and substrate as well as other variables and complexities at the site. Habitat requirements depend upon the fish species in question. Some species are “broadcast spawners” that freely spawn over the substrate. Other species construct and deposit their eggs within nests or “redds” in the substrate. Some species’ spawning habitat is present in riffle-pool channel morphology associated with debris accumulations or in pool tailouts and other localized accumulations of gravel. Other species depend on wide gravel beds with uniform cross section and profile, known as “runs.”

Spawning habitats are directly created by and depend on channel characteristics and complexities that cause hydraulic sorting and accumulation of gravel into bed forms appropriate for spawning. These beds, if well established, are relatively resistant to scour during periods of egg incubation. Changes to the bank can cause the thalweg to scour gravel accumulations and create uniform channel beds that eliminate spawning habitat. Where banks are smoothed by natural or man-made influences, riffle-pool sequences and other spawning habitats are lost forever. Spawning-habitat losses are difficult, if not impossible, to recreate without regenerating the channel characteristics they depend on. This is especially true in channels that are too narrow to include large roughness elements or debris accumulations.

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Mitigating the loss of spawning gravel includes recreating and/or maintaining channel dimensions and complexity. Depending upon the species, the scale of the channel and associated impacts, channel-complexity mitigation might include adding debris jams, debris catchers, channel constrictions, drop structures and roughness elements. Even under the best of circumstances, however, it is not always possible to recreate spawning habitats.

An important source of spawning gravel is the material eroded from its banks. Successful bank-protection projects often block the ability of channels and banks to continue supplying spawning gravel. Spawning sites in channels whose supply of gravel is lacking are particularly sensitive to these impacts. Lack of spawning gravel might be a natural situation or may be due to previous unmitigated bank-protection projects or dams. Artificially supplementing the channel with spawning gravel allows the channel to redistribute it during floods.

Cover

The term “cover” refers to juvenile rearing and adult holding habitats provided by large woody debris, live tree roots, deep pools, shallow water (refuge for juveniles), undercut banks, overhanging vegetation, turbulence and large interstitial areas in cobble or boulder substrate. Fish use and value of these habitats vary with different species and life stages. Especially important in lower river reaches, fish-migration corridors provide holding areas for fish that are not ready to enter saltwater or that are migrating at night and holding during the day.

Cover provided by complex debris structures is the habitat preferred by most fish. Deep, low-velocity pools resulting from scour around debris structures, debris, snags and jams in or near the water should be left in place. If they must be moved to facilitate construction, they must be replaced in their entirety either in the original position or a location where they would naturally occur in order to maintain the original habitat function. An alternative to replacement is to install debris collectors that capture and retain floating debris. It may be tempting to use boulders or groins to create pools in the stream for fish. The problem with such a solution is that fish tend to use these pools less than those created by wood. Therefore, boulders or groins alone are not a good substitute for

wood. However, when groins are combined with substantial accumulations of wood, they have been shown to provide comparable habitat to that created by naturally accumulated woody debris.

Armored revetments create a continuous, deepened thalweg, an uninterrupted, high-velocity pool, along the treated bank. Placement of dense clusters of large wood in the channel and along the banks will break up the current. The track record for attaching large woody debris to riprap, particularly for single pieces, has been poor; except when specifically designed for the shear stress at the site and buoyancy of the wood. Log jams and pile structures as debris catchers have been successful when designed to fit natural channel processes. Shallow water is an important cover feature for juvenile fish use where more complex cover habitat is not available. Juveniles use shallow water to escape predatory fish. Shallow-water cover is not a replacement for cover provided by debris and scour; however.

Habitat Complexity and Diversity

Habitat complexity and diversity is the mix of in-channel and hydraulic features important to the survival, growth, migration and reproduction of salmonids. Complex and diverse channels are more productive for salmonids than simple channels. Vegetated banks and floodplain, cover, off-channel rearing, flood refuge and spawning are habitat components that partially define complexity and diversity of a stream channel. Variations in bank and bed topography, substrate, depth and velocities are all elements of diversity.

Riparian Function

Riparian corridors serve a vital role in fish and wildlife habitat. Riparian benefits include food contribution in the form of leaf litter and insects, shade, nutrients, cover, large-woody-debris accumulation, attraction of wildlife and a high level of water quality. Riparian corridors also provide energy dissipation, bedload retention, pool formation, flood-refuge habitat and critical habitat diversity. To maintain and protect the riparian function, it is important to preserve a natural riparian buffer within and beyond the bank protection.



All bank-protection projects should have a riparian preservation or restoration component. Riparian function is partially mitigated at armored banks by planting vegetation that will grow through the hardened bank armor. This is not always feasible depending upon the thickness of the rock and filter blankets, as well as water conditions in the bank. If the bank armor cannot be vegetated because of materials or maintenance requirements, another style of bank protection should be considered, or the loss must be mitigated by establishing a riparian buffer in the area above the rock, including large trees and native under-story plants. Controlling invasive, noxious weeds is critical in re-establishing native riparian vegetation.

Every linear foot of bank that has received protection treatment should have the riparian function restored, including trees, other woody species and under-story vegetation. Be sure to integrate plantings into the bank treatment or create or enhance a riparian habitat area in a bank terrace and above the bank face. Part of the mitigation design and management is to assure a specific plant survival rate over a specific period of time. For example, a mitigation plan could stipulate that 80 percent of the intended riparian vegetation survives and develops to specific dimensions within three years.

Flood Refuge

Riparian habitat often provides refuge for juvenile and adult fish during floods. It can be created by installing debris collectors (such as rows of pilings) or mature, woody vegetation on the upper bank and in the floodplain.

When armored revetments are put in place, they create smooth banks that limit floodplain and bank roughness features. Debris collectors and vegetation create current breaks, which provide flood refuge, juvenile rearing habitat and holding cover for adult fish. Planting trees in the riparian buffer creates refuges and is also effective in roughening the channel. Vegetating rock armor and/or building a terrace into the revetment above the ordinary high-water line will also provide some mitigation. Large-woody-debris structures anchored into rock armor above the ordinary high-water line will provide some refuge as well.

Sediment and Debris Sources

Sediment and woody-debris sources are lost if a channel is fixed in place and not allowed to gradually erode and recruit material.

Trees removed from rights-of-way or streambanks for safety purposes and debris removed from reservoirs should be relocated or placed within the stream channel so they can function as habitat. Artificial feeder banks can be developed for a reach to mitigate the cumulative loss of sediment sources due to bank protection. Gravel bars and gravel bluffs have proven effective when constructed and maintained as gravel sources downstream of reservoirs.

Off-Channel Rearing Habitat

Off-channel rearing habitat, including wall-based channels, flood swales, side channels and floodplain spring channels, is often a limiting factor to salmonid productivity in channelized rivers. Common functions of these habitats include spawning, rearing and holding habitats, and refuge for adults and juveniles of many fish species.

In-kind mitigation should be required for any project that eliminates off-channel habitat or reduces the opportunity for the creation of off-channel habitat in the future. If no on-site opportunities for habitat restoration exist, or land ownership precludes their use, the project owner should contribute to the creation of such habitat elsewhere. If land is not available for off-channel work, then an off-site restoration effort on other river stretches may fulfill this habitat need.

Lost-opportunity impacts can be avoided by selecting a bank-protection technique that is deformable and provides for natural rates of lateral erosion, such as a log or vegetated bank toe or debris jam to restore the channel processes to their natural rate. Construction or restoration of off-channel habitats and providing an artificial supply of debris and sediment can also help mitigate the loss. However, mitigation must be provided in perpetuity and a long-term commitment is required for mitigation which precludes natural fluvial processes. Off-channel habitats are a logical application of mitigation banking.



Funding for off-channel habitat mitigation can be accomplished by consolidating the impact fees of multiple small projects. Diking districts can combine their funding into projects of reasonable and effective scale, distributing the cost among off-channel beneficiaries through their taxing structure. Fees can include administrative costs, and cost matches from other programs should be encouraged.

DURATION AND EXTENT OF IMPACTS

It is important to understand the specific potential impacts that bank-protection treatments have on stream function and fish habitat. Without this level of understanding, treatments may be selected that have unintended but severe consequences to the ability of the stream or river to support life. There are five types of impacts associated with bank-protection projects:

1. construction activity impacts;
2. direct loss of habitat;
3. channel response impacts, both on- and off-site;
4. lost opportunity; and
5. increased risk by perception of protection.

Construction-Activity Impacts

Construction-activity impacts to the riparian corridor and the channel can often be avoided. Construction activity that causes impacts is often short-term, though impacts to a mature riparian area may take decades or centuries to recover. Short-term impacts can usually be addressed and minimized by construction timing and sequencing, water-quality protection techniques, work-site isolation, revegetation, and erosion- and sediment-control practices. The impact that heavy equipment has on a streambank construction site is often significant, depending upon the type of equipment used, care of equipment operation, site-access design, project sequencing and the care equipment operators take in conducting their work. Long-term construction impacts are caused when riparian vegetation is removed along the bank or in the water; when soil is compacted, when surface drainage is changed or when heavy equipment is repeatedly used for maintenance.

Impacts include tree removal, erosion of bank and disturbed soils, release of sediment to the water, road construction, soil compaction, channel and bank

reconfiguration and debris removal. Construction impacts must be mitigated at the time of project construction. Mitigation is usually covered with standard Hydraulic Project Approval provisions that usually include construction timing, project sequencing, water-quality protection, equipment type and operating procedures, revegetation, and best-management practices for erosion and sediment control.

Direct Habitat Loss

Direct habitat loss is the immediate and permanent alteration of habitat by a project. It is also the lost ability of a site to naturally restore the habitat functions associated with it. Direct loss of habitat may include loss of cover, spawning beds, individual pieces or accumulations of debris, riparian function and alterations to the channel that decrease the complexity or diversity of habitat. It may also include interference with the hyporheic function of the stream. Treatments that prevent a channel from naturally restoring itself include placement of permanent structures that eliminate habitat-forming dynamics such as pool scour, debris accumulations, and overhanging trees and/or debris.

Channel Response Impacts: On Site, Off Site

One of the most unpredictable impacts of bank-protection projects is their off-site effect on stream function upstream or downstream. Channel-response impacts include effects of redirecting flow, modifying energy dissipation through the project reach and/or disrupting natural meander migration patterns. The impacts are to the adjacent channel upstream and downstream of the project. Impacts can be positive, depending upon the mechanisms and causes of failure. However, they can also negatively impact not only fish habitat, but also property and public safety.

Indicators of potential off-site impacts include changes in flow alignment, energy or sediment delivered past a project site or changes in backwater conditions upstream and, therefore, a change in sediment deposition and channel stability and hyporheic function. These changes may not be obvious or immediate. They are created by the influence of the project on the channel over time and during future floods. Channel confinement, constriction, smoothing or roughening, alignment changes and channel shortening may jeopardize adjacent habitat and properties. Indirect, off-site impacts are the most difficult to



Channel-response impacts include redirecting flow, modifying energy dissipation through the project reach and/or disrupting natural meander migration patterns.

predict and mitigate and may take years before they are discernable or they may occur during the next flood event. Once they occur, however, they are typically persistent and create even more channel instabilities. Despite the difficulty of identifying the potential off-site consequences of different bank-protection techniques, an attempt must be made during the reach analysis and design phase.

Mitigation should be conducted concurrently with the bank-protection project. Mitigation for off-site impacts avoids the indirect loss of habitat in adjacent reaches as a result of a bank-protection project. The best mitigation, again, is to avoid the impacts altogether by not constructing the bank protection or by selection of an appropriate treatment that avoids the impact.

Mitigation for upstream and downstream channel-stability impacts can include acquisitions, protective covenants, conservation easements and restoration of natural banklines in adjacent reaches to minimize impacts from the project. While there is an equity issue in asking for mitigation of lost opportunity when the perpetrator of the problem (e.g. upstream land owner) was not required to mitigate for their previous actions, that issue does not relieve the responsibility of project mitigation.

Lost-Opportunity Impacts

Lost-opportunity impacts result from projects that adversely alter natural fluvial processes important to the ongoing creation of fish and wildlife habitats. Habitat diversity for a variety of life-cycle stages of fish and wildlife depends on natural rates of lateral channel erosion.

Habitat diversity for a variety of life-cycle stages of fish and wildlife depends on natural rates of lateral channel erosion.

Debris, sediment sources and sorting, habitat complexity, pools, and side channels are examples of habitat components that depend on erosion. Preventing a channel from naturally migrating across the floodplain usually eliminates sources of woody debris, sediment and side channels; these losses are defined as “lost opportunities.” Natural channels evolve over time and migrate across their floodplains. When a channel naturally moves to a new alignment, it leaves behind vital habitat, such as floodplain sloughs and side channels. Those habitats have a finite productive longevity, some likely less than 20 years. If the natural fluvial processes of a stream are restricted or interrupted, these side-channel habitats will diminish in productivity and will not be replaced. These habitats cannot be mitigated by the design of a project. They are lost when a channel is fixed in a specific location, regardless of the bank-protection technique. Lost-opportunity impacts last as long as channel migration is halted (see *Figure 4-1* for an example of lost-opportunity assessment).

Mitigation for lost opportunity requires mitigation for channel processes affected by a project. In some situations, off-site mitigation may be the only option. It may be more efficient and cost-effective for small landowners in a watershed to consolidate their mitigation work.

Mitigation for lost opportunity requires mitigation for channel processes affected by a project.

Though it is recognized that, to achieve no loss of habitat, lost-opportunity impacts must be mitigated, there are currently no tools for universal and consistent application of the concept. Tools are needed to assess the lost opportunities in order to ensure that appropriate mitigation is provided. The concept of mitigation for lost opportunity should only be applied when consistent, acceptable, assessment methods or specific site information are available.

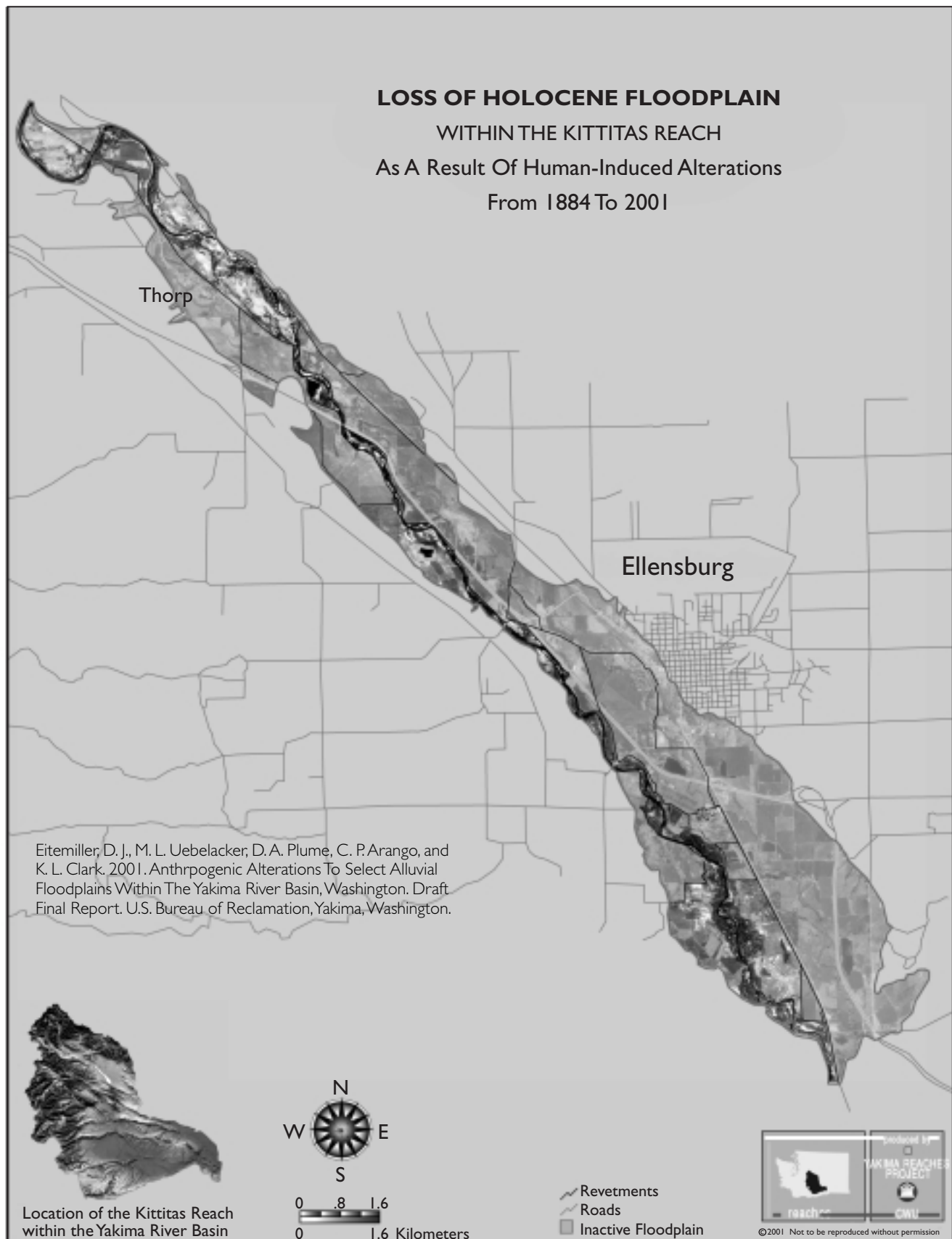


Figure 4-1. An example of lost-opportunity assessment, in this case, loss of floodplain.



Management of Lost-Opportunity Impacts

Lost-opportunity impacts should be recognized early in the scoping of all projects, especially those projects that are large and complex. Recognizing and mitigating lost opportunities within the context of an entire stream reach is far more efficient, practicable and preferable than focusing only on individual projects. This approach is most feasible for property owners and public agencies that have access to extensive lands along the stream basin or in areas with cooperative planning among landowners.

The process of identifying lost opportunities and determining their mitigation includes conducting a corridor analysis, studying the overlay of existing infrastructure, studying projected land use, and identifying ecological characteristics that might be affected by the interaction of the river and the proposed work (see Figure 4-1). An alternatives analysis could then identify treatment options for the entire corridor. This brings additional partners into the assessment process such as neighboring property owners and other interests in the basin. It allows efficient use of combined resources and allows a proactive approach to stream corridor management when designing both projects and mitigation.

Different protocols might be appropriate for assessing different scales and levels of lost-opportunity analysis. For example an analysis using typical channel characteristics might be used in the planning phase of a large project. That analysis might be expanded and/or verified as part of the project development through a geomorphic analysis of the reach and site.

Recognizing Lost-Opportunity Impacts

There are three key elements to identifying lost opportunity:

1. expected duration of impact,
2. geomorphic/riparian basis, and
3. the action/treatment being considered.

Expected Duration of Impact

The expected duration of the impact establishes the timeframe through which mitigation must be considered. Channel processes by definition are time dependent; over time, a channel may continue to move and create habitat. Lost-opportunity impacts, therefore, should also be considered continual and changing; cumulative impacts may continue to occur as long as a treatment is present.

Impacts of a project might also last beyond the project's existence. If a bank-protection treatment is removed, its impact of altering the channel form, shape, slope and location may continue until the channel regains its natural character and process. It is important to pay close attention to the concept of "life of project" discussed later in this section.

Geomorphic/Riparian Basis

The geomorphic/riparian basis of lost opportunity is the physical setting and the natural processes that might be affected by a project.

There are four parameters in the geomorphic/riparian basis:

1. channel and floodplain characteristics;
2. current, natural and expected rates of erosion;
3. extent of area affected; and
4. opportunities affected.

The character of a channel in which work is proposed will help determine the impacts expected. For example, stabilizing a channel in a ravine that migrates very little laterally over the life of the project may result in little or no lost opportunity. On the other hand, stabilizing a channel that once meandered freely across an alluvial floodplain may present substantial lost opportunities. Meandering reaches produce valuable oxbows and cutoff channels, and avulsing reaches create beneficial side channels.



The channel-migration zone, relative to the expected life of the protection treatment, generally defines the aerial extent of the actual or potential impact, though additional hyporheic zone impacts may extend even further.

The channel-migration zone, relative to the expected life of the protection treatment, generally defines the aerial extent of the actual or potential impact.

Lost-opportunity analysis should include time averaging to identify issues such as habitat types, diversity and presence, debris and sediment recruitment rates, successional stages and growth rates of riparian vegetation, life cycles of various fish and wildlife, water quality, and channel processes. It should also identify lost opportunities as if the floodplain were in a natural condition. "Natural condition" is described in terms of presence of side channels and forests as well as in terms of rate and pattern of erosion and channel migration. This is because a floodplain would be less developed if it were not for the

presence of bank-protection work. In other words, clearing and developing the floodplain is at least partially the result of bank-protection work rather than a pre-existing condition. It also provides a simple and common baseline for assessing the condition of the watershed, hydrology and sediment inputs that might affect the site.

A dichotomous key or flow chart such as the example below can be used to analyze the potential for lost-opportunity impacts: (see *Figure 4-2*)

Action/Treatment Being Considered:

The third element of lost-opportunity analysis is the design and scale of the project or action being considered. A project that is designed to be deformable, so that the channel can eventually return to a natural rate of erosion, will likely have very different lost-opportunity impacts than a project that rigidly and permanently fixes a migrating channel in place.

Bank-protection treatments installed in inappropriate locations more often than not create the need for further bank protection and ultimately result in loss of opportunities for the entire reach. Those responsible for initiating the first bank protection along a reach may be liable for impacts to the entire reach. On the other hand, whoever

What floodplain and channel processes might be impacted by the project?

- Are there remnant side channels present or anticipated?
 - ☐ Yes. Consider lost opportunity of off-channel rearing and/or spawning habitat.
 - ☐ No. Further lost-opportunity assessment is needed.
- Could the riparian area to be affected by the project be a source of debris?
 - ☐ Yes. Consider lost opportunity of debris source.
 - ☐ No. Further lost-opportunity assessment is needed.
- Could the riparian area be a natural source of sediment that could be important to spawning habitat function?
 - ☐ Yes. Consider lost opportunity of debris source.
 - ☐ No. Further lost-opportunity assessment is needed.

For all "yes" conditions, consider the extent of lateral migration relative to the expected life of the project, and the frequency and nature of expected off-channel habitat, debris and sediment sources that contribute to the lost opportunity.

Figure 4-2. A dichotomous key used to analyze the potential for lost-opportunity impacts.



installs bank protection along the last remaining unarmored section of a river reach might be considered the victim of previous actions and may therefore be held to a different standard of mitigation liability. They may be held liable for no more than the direct impact at the site of their bank-protection treatment.

Impacts of Perceived Protection

Bank-protection treatments often create a false perception that properties adjacent to the channel are now safe from flooding or erosion. This false sense of security can buoy confidence to increase land development, which in turn may increase the risk associated with future bank erosion. Special caution needs to be taken in land-development planning and streambank management to account for such a risk.

MITIGATION

This section describes appropriate fish-habitat mitigation measures. The following concepts are intended specifically for bank-protection projects but might also be appropriate for other types of projects.

Bank erosion is a natural process that is often accelerated by human influences. Mature, overhanging trees, shrubs and exposed roots in a gradually eroding bank are important for creating and maintaining habitats. The recruitment of debris and gravel also perform vital habitat- and erosion-protection functions. Although a bank-protection project may control the introduction of excessive sediment, armoring a streambank stops ongoing development of a healthy and dynamic riparian ecosystem. The habitat-creation benefits of debris from an eroding bank can be more important to biological processes than the reduction of the sediment source. Bank-protection projects may preclude the possibility of restoration of the natural bank and riparian functions.

The first priority of mitigation is to avoid impacts to habitat. Where all impacts are avoided, mitigation is complete. On the other hand, where a bank-protection project causes impacts to habitat, compensatory mitigation (rectifying, compensating or correcting) will be required.

The first priority of mitigation is to avoid impacts to habitat.

Legal and Policy Basis of Mitigation

The required level of mitigation is described in Washington Department of Fish and Wildlife regulations, Washington Administrative Code (WAC) 220-110-050: *Bank protection projects shall incorporate mitigation measures as necessary to achieve no net loss of productive capacity of fish and shellfish habitat.* Mitigation is defined in the WAC as actions taken to avoid or compensate for impacts to fish life resulting from the proposed project activity.

The Washington State departments of Ecology, Fish and Wildlife, and Transportation, as well as Tribes in Washington have worked together to develop policy guidance for mitigation alternatives within a watershed context. This guidance has been compiled in a document called *Alternative Mitigation Policy Guidance - Interagency Implementation Agreement (AMPG-IIA)*, published February, 2000. Additionally, the Washington Department of Fish and Wildlife has developed a mitigation policy (POL-M5002, Jan. 18, 1999).

The concepts presented in this section are intended to provide further explanation and detail to existing mitigation policies and regulations. If there is any discrepancy between these policies and regulations and the information related in the *Integrated Streambank Protection Guidelines*, the policies and regulations prevail.

The AMPG-IIA defines mitigation as:

"...actions that shall be required or recommended to avoid or compensate for impacts to fish and other aquatic resources from a proposed project. Mitigation shall be considered and implemented, where feasible, in the following sequential order of preference. Use of the word 'mitigation' is comprehensive of all three parts of the following sequence and is not to be considered as synonymous with compensatory mitigation.



Complete mitigation is achieved when these mitigation elements ensure no net loss of ecological functions, wildlife, fish and aquatic resources. Avoiding the Impact altogether by not taking a certain action or parts of an action. Minimizing the Impacts by limiting the degree or magnitude of the action and its implementation. Compensating for the Impact by replacing and providing substitute resources or environments through creation, restoration, enhancement or preservation of similar or appropriate resource areas."

This sequence of mitigation decision making is the basic foundation of the bank-protection design process described in the text and matrices of Chapter 5.

The most elegant bank-protection solution mitigates by avoiding habitat impacts and, in fact, restores or enhances habitat.

Mitigation success is evaluated based on the *biological productive capacity and opportunities reasonably expected of a site in the future* (Washington Department of Fish and Wildlife Mitigation Policy, 1999). This statement recognizes that an eroding channel is not static; in the process of erosion, habitats are formed. Likewise, mitigation measures should be allowed to evolve as the channel evolves.

The stream's biological capacity and habitat potential should be incorporated into the project design. An understanding of the stream's biological characteristics and the effects of a bank-protection project are essential in order to assess the habitat impacts and habitat potential of a site and reach. A detailed discussion of these needs for various species of fish and wildlife and at various life stages is provided in Appendix G. An annotated bibliography, prepared by the U.S. Army Corps of Engineers, is also included in Appendix K, *Literature Review of Revetments*. It describes biological effects due to stream channelization and bank stabilization.

The most elegant bank-protection solution mitigates by avoiding habitat impacts and, in fact, restores or enhances habitat.

Avoiding the Impact

If a project requires a federal permit from the Corps of Engineers, the Federal Memorandum of Agreement called, "Memorandum of Agreement between the Environmental Protection Agency and the Department of the Army Concerning the Determination of Mitigation under the Clean Water Act, Section 404(b)(1) Guidelines," will apply. The memorandum states "*the determination of avoidance requirements will not be based on characteristics of the proposed projects such as need, societal value, or the nature or investment objectives of the project's sponsor.*" It is important to note that the Federal Clean Water Act and Memorandum of Agreement require that the "*least environmentally damaging and practicable alternative (as determined by the Corps and EPA) may be permitted.*"

Avoidance of impact requires relocation of the proposed project if:

- alternatives are available for nonwater-dependent activities that do not involve special aquatic sites, or
- alternatives are available that have less adverse impacts on the aquatic environment than the proposed impact site (AMPG-IIA).

When applying for state permits, a project proposal should have all aquatic resources delineated, and project proponents should examine avoidance alternatives (AMPG-IIA).

Minimizing the Impact

Minimization refers to actions taken on a site to reduce impacts that will occur to aquatic resources. An applicant must first demonstrate to the permitting agencies that complete avoidance of impacts is not practicable.



Compensating for the Impact

For those impacts that are determined to be unavoidable, The Washington State Department of Ecology poses seven questions when planning compensation of unavoidable impacts (AMPG-IIA):

1. What are the species, habitat types or functions being adversely affected?
2. Is replacement or reintroduction of the species, habitat type or functions vital to the health of the watershed? If so, do they need to be replaced on site to maintain the necessary functions?
3. If it is determined that on-site, in-kind replacement is not necessary, are there higher-priority species, habitat types or functions that are critical or limiting within the watershed?
4. If both on- and off-site compensatory mitigation is available, will the species, habitat type or functions proposed as off-site compensatory mitigation provide greater value to the health of the watershed than those proposed as on-site?
5. How will the proposed compensatory mitigation maintain, protect or enhance impaired functions or the critical or limiting functions of a watershed?
6. Will the proposed compensatory mitigation have a high likelihood of success?
7. Will the proposed compensatory mitigation be sustainable in consideration of expected future land uses?

For those impacts that are determined to be unavoidable, the Washington Department of Fish and Wildlife mitigation policy states that priorities for compensatory mitigation location and type, in the following sequential order of preference, are:

- on-site, in-kind;
- off-site, in-kind;
- on-site, out-of-kind; and
- off-site, out-of-kind;

The department's preference for sequencing alternatives does not prohibit project proponents from initiating off-site and/or out-of-kind actions if they are better than on-site, in-kind actions. Off-site and/or out-of-kind compensatory-mitigation activities might be appropriate for specific mitigation targets as described later in this chapter under *Compensatory Mitigation Target*.

Mitigation Concepts for No Loss-of-Habitat Functions

The following concepts are essential to avoiding loss-of-habitat functions and values when compensatory mitigation is required. The concepts in this section relate to compensatory mitigation; they are about *rectifying, compensating or repairing* habitat impacted by a project. The concepts described here have common requirements related to habitat function, performance standards, monitoring and adaptive management.

Mitigation for the Duration of the Impact

To avoid loss-of-habitat functions and values, impacts of a project must be mitigated for as long as they persist. Many habitat features have finite lives, regardless of whether they are naturally occurring or constructed as mitigation. Some specific mitigation features may not be expected to persist as long as the bank-protection project that they are intended to mitigate. A habitat feature may fail structurally or functionally. Ideally, mitigation should be “deformable,” or adaptive, just as the natural channel is. If compensatory mitigation fails or deteriorates in function, it should be modified, replaced or supplemented unless the failure is due to unanticipated watershed conditions. If full compensatory mitigation is provided and it continues to succeed, no additional mitigation is needed. If the natural character and function of the river or stream return to an impacted site, mitigation is complete for those elements of the impact.

To avoid loss-of-habitat functions and values, impacts of a project must be mitigated for as long as they persist.

Mitigation plans should include clear mitigation objectives and project-impact and mitigation-monitoring procedures, as well as a process by which mitigation can be modified, replaced or supplemented as necessary. Monitoring plans should evaluate the success of mitigation and its duration, as well as performance standards and adaptive measures for correcting inadequacies in the mitigation.



For example, a piece of woody debris placed as a mitigation feature may over time either be buried in sediment as the channel migrates away from it, or it may be washed downstream and become stranded on a gravel bar. In either case, is the mitigation still effective? The essential question is whether the presence of the bank-protection project precludes the habitat from recovering and whether or not the debris performed as intended. The buried piece of debris will still be in place and be effective when and if the river moves back to it. Whether the mitigation for the displaced piece of debris is effective or not depends on its initial purpose and as defined by the mitigation plan. If it had been placed to supply the channel with debris that is precluded by the bank protection, then its specific location is not essential. In fact, it may be more appropriate in its relocated position. If, on the other hand, the displaced debris was intended as mitigation for the on-site loss of overhanging structure and complexity in the bank, then its function may have failed. Clear objectives of mitigation activities are essential to the determination of success or failure of the mitigation.

Reopening Mitigation for Life of the Project

The success and effectiveness of mitigation measures should be evaluated throughout the design life of the project. Since mitigation is normally applied for the expected life of a project, the mitigation should be “reopened” for consideration and revision if the life of the project is extended. In such a case, mitigation is evaluated and reconsidered almost as if it were a new bank-protection project.

For the purpose of these guidelines, the “life of the project” is concluded when the impact, frequency and scale of maintenance, repair or reconstruction activities exceed a predetermined threshold. This threshold can be exceeded even though the project itself may still function satisfactorily for its primary objective.

This means that repair or reconstruction that exceed a threshold, or replacement of the structure, will reopen mitigation considerations. This does not mean that additional mitigation will be required for impacts that occurred earlier in the life of the bank-protection project. The assumption is that mitigation was provided for the previous impacts caused by the existing structure. It does mean that mitigation may be required for impacts of the project continuing into the future.

The mitigation reopener determines whether the initial mitigation for the presence of the project and directly related development is still effective for the proposed extended life of the project. If the mitigation is not adequate, complete mitigation should be a requisite of the current activity. It's often not realistic or practical to get full mitigation for the presence of a facility before repairs must be made to protect life, property and infrastructure.

The following activities would not normally trigger a mitigation reopener:

- activities that have insignificant impact over time;
- normal maintenance and repair; defined as structural activity that returns the facility to as-built condition as long as there is no change in course, current or cross section; and
- repair of damage due to watershed conditions that were reasonably unanticipated.

There are two key reasons for reopening mitigation:

1. project reconstruction, and
2. chronic maintenance or repair.

Major project reconstruction and chronic repair of a project are actions that extend the duration of a project. They are also logical points at which to reopen the mitigation plan in order to re-evaluate and/or revise it as appropriate. Reopening the mitigation plan determines whether the initial mitigation for the presence of the project is still effective for the extended life of the project. If the mitigation is not adequate, complete mitigation should be a requisite of the current activity. This step isn't intended to evaluate the adequacy of the mitigation for past impacts; it considers the adequacy of mitigation only for the future extended life of the project.

There currently is no detailed protocol for universal and consistent application of the concepts described here as “life of the project” and “mitigation reopener.” Development of specific thresholds as described in this section and a clear expectation of the action expected at the end of the life of the project are needed. The concept of mitigation for the duration of the impact should only be applied at this time where consistent, acceptable methods are available. There are habitat-assessment tools that can help estimate the duration of impacts and the longevity of



mitigation function. Specific monitoring protocols are described and evaluated in *Inventory and Monitoring of Salmon Habitat in the Pacific Northwest - Directory and Synthesis of Protocols for Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia*, published by the Washington Department of Fish and Wildlife.¹

Three project timeframes should be included as tools and methods are developed:

1. existing projects,
2. projects in the planning and development pipelines, and
3. new projects.

Design criteria for new projects are generally more conservative and should include mitigation for duration of the project. It is essential that designers of new projects incorporate a realistic and thorough environmental analysis into the early cost/benefit analysis.

Mitigation for Project Reconstruction

Project reconstruction can be a cause for reopening mitigation. What qualifies as project reconstruction is a matter of scale of both the project and the impact of its presence.

The following examples define reconstruction that would cause a mitigation reopener:

- a repair or modification that measurably confines or constricts the channel beyond the original design or changes the course, current or cross section of the channel beyond the original design;
- work that extends the design life of the project, including reconstruction of the project;
- repair work or structural replacement that is required as a result of damage from a flood that is greater than the project was designed to withstand. Hydraulic structures are commonly designed to withstand a specific flood recurrence level. They are not expected to be fully functional or to survive at flood events greater than the design flow. Such repair and/or replacement work can be considered to be a new project; and
- work that exceeds a specific design or maintenance threshold or criteria for the type of facility. For example, a current standard for new bridge piers is that they will not require scour protection in their lifetime. If scour protection becomes necessary, the design life of the bridge would be over, and mitigation would be reopened.

Increased peak events, increased sediment loads due to upstream land uses or hydraulic influences of nearby projects may affect the life of a project. The concept of *Integrated Streambank Protection* requires that future watershed conditions be considered in any project design. Project mitigation should consider the presence of the project in current and future channel and watershed conditions. If future conditions were predictable, those conditions should not lessen the mitigation responsibility or prevent the mitigation reopener. Anticipation of watershed conditions more than about 20 years into the future is not likely practical. A project that does not define and design for watershed conditions reasonably expected to occur in the future should not be exempt from mitigation reopener triggered of damage due to changes in watershed conditions. Anticipated future conditions must be clearly defined in mitigation plans.

It is recognized that there are both expected and anticipated conditions, and there are unanticipated and unpredictable future conditions. The further into the future that conditions are projected, the less certain the predictions are. Projects would only be expected to design for anticipated and expected conditions that are likely to occur within 20 years. City and county planning departments can assist in providing projections for future conditions, based on expected rates of growth and development. In addition, the Washington State Department of Natural Resources and private timber companies have long-term timber harvest projections, and many are now committed to 50-year Habitat Conservation Plans, which can be used to determine expected land-use actions.

Mitigation for Chronic Maintenance or Repair

Some level of normal maintenance and repair activity is expected during the life of most bank-protection projects and, except for the operational impacts of maintenance activities, should be mitigated as part of the initial project. A “chronic” level of repair is defined as that which exceeds expectations of frequency and magnitude as identified in the initial project and may indicate that the life of the project is exceeded. Mitigation should be considered in this case as if it were a new project.



The following activities should *not* trigger a mitigation reopener as chronic activities:

- normal maintenance and repair, defined as structural activity based on a normal frequency of work for that type of facility;
- normal maintenance and repair, defined as structural activity that returns the facility to as-built condition, as long as there is no change in course, current or cross section; or
- damage from large flood events, even if they are frequent.

Some projects may have maintenance plans that specifically define normal maintenance expectations. Maintenance plans encourage good design.

When the frequency of an activity exceeds an acceptable threshold established for a specific types of facility, it should be considered to be chronic, triggering a mitigation reopener. Tracking maintenance and repair activities at facilities is helpful in defining which maintenance activities are chronic. Chronic levels of some types of activities should be defined by reach rather than specific location. For example, a road that encroaches on a channel migration zone for some distance may be threatened by bank erosion at multiple individual locations. The activity that might be chronic in that case would be the bank-protection activity along a distance of the road and include multiple individual erosion sites.

The Washington State departments of Ecology, Fish and Wildlife, and Transportation are jointly developing thresholds and examples to help define chronic activity.

In addition to these options, large-property owners or public agencies might maintain a chronic repair list and a rotating budget to resolve projects on the list. Chronic repair projects would automatically be added to the list. Additional project tracking will be needed to maintain chronic repair lists. Such lists might also include chronic needs for maintenance of habitat mitigation features. Mitigation maintenance would increase the importance of resolving a chronic problem.

Probability of Mitigation Success and Delayed Mitigation

Like bank-protection projects, mitigation work has inherent uncertainties of success. Some portion of compensatory mitigation projects will fail structurally; others will fail in function. Success or failure depends partially on the quality of design and construction, the ability of the design to accommodate fluvial processes and the type and extent of mitigation required. Many mitigation activities also have a delay until they are fully functional or may function with varying degrees of success over time. For instance, vegetation planted as mitigation for loss of cover and food source habitats take years to develop and become fully functional. This time lag results in an interim loss of habitat function. A stream may migrate to or from the mitigation site, resulting in varying degrees of performance for a specific function.

There are several methods of dealing with the uncertainty of success and delay of mitigation function:

- mitigation banking,
- monitoring and corrective action,
- mitigation ratios, and
- experimental mitigation techniques.

Mitigation Banking

In some situations, mitigation is required prior to project construction to ensure its completeness. Successful mitigation banking eliminates reduces mitigation risk and delay and might be appropriate to adequately mitigate project-related impacts.

Sometimes, the mitigation habitat benefit achieved is actually more than 100 percent. In other instances, it is impossible to adequately mitigate a project. When mitigation exceeds success requirements, the project may receive credits for mitigation and would be considered mitigation banking.



Monitoring and Corrective Action

It will be necessary to monitor the success of mitigation and take appropriate corrective action to ensure its success. Monitoring requirements may be more prevalent in the future under federal consultation through the Endangered Species Act. More is included about monitoring in the section titled, “Maintenance, Adaptive Management and Monitoring” of this chapter. Specific monitoring protocols are described and evaluated in *Inventory and Monitoring of Salmon Habitat in the Pacific Northwest - Directory and Synthesis of Protocols for Management/ Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia*, published by the Washington Department of Fish and Wildlife.¹

Mitigation Ratios

Another way to deal with uncertainties and time lag is by using mitigation ratios. A project proponent can provide compensatory mitigation at a rate greater than the anticipated impact of a project with the expectation that a portion of the mitigation may not be functional. For example, twice as much habitat might be constructed as mitigation replacement for the quantity of habitat lost by a project with the expectation that half of the new habitat may fail either structurally or functionally. It is not possible to quantify appropriate ratios for every type of mitigation activity. Mitigation ratios are applied to wetland mitigation projects and are based on the proportion of functional success of previous wetland construction projects. Applied ratios need to start conservatively. Their accuracy will be more assured if restoration monitoring is increased and if there is a high motivation for success. The ratio can also vary with the construction technique and care of construction, monitoring and follow-up work.

Mitigation ratio considerations for a specific impact might include the following questions:

- What is the level of certainty of success of the mitigation feature for the duration of the impact?
- Is the proposed mitigation technique proven to be successful or is it experimental?
- What is the level of certainty that the mitigation feature will be constructed as intended?

- Is the mitigation feature self-maintaining and what is the certainty of follow-up or corrective actions necessary to maintain full mitigation function?
- What is the time lag between the initial project impact and the full maturity of the mitigation?
- Will the mitigation function vary over its life?
- What is the importance of the impacted habitat to the fish and wildlife that depend on the mitigation? Is the habitat unique or does it limit productive capacity?
- What is the status of impacted fish or wildlife?
- What is the mitigation target of the project (see *Compensatory Mitigation Target* later in this chapter).

It is important to understand that none of the concepts in this section constitute habitat restoration or enhancement; they are meant to provide full and complete project mitigation. In other words, the intent of mitigation banking and ratios is to prevent loss of existing habitat, rather than to improve habitat beyond original condition. The section in this chapter on *Compensatory Mitigation Target* may lead to mitigation objectives of habitat restoration.

Experimental Mitigation Techniques

Some habitat mitigation measures, including some described in this document, are considered experimental. Their experimental nature might either be in their basic concepts or in their specific applications. Either the structure or its habitat function may be considered experimental. Experimental measures are encouraged as long as the risk of structural and mitigation functional failure are appropriately addressed. These risks are addressed by applying experimental mitigation to low-risk projects (e.g., retrofits, restoration, low-resource-value sites, small projects) and by providing guarantees of mitigation success (e.g., experimental plan, financial guarantee). The resource regulatory agencies have final approval for application of experimental measures.

The Washington Department of Fish and Wildlife Mitigation Policy requires that if experimental techniques are used, they must be constructed and proven successful before they can be counted as mitigation. This essentially says that experimental mitigation techniques can only be used in mitigation banking situations.



If an experimental mitigation technique is applied before it is proven, an experimental plan must be approved by appropriate resource agencies to eliminate the risk of partial or complete failure. Such a plan must include:

- a *contingency plan and a commitment to upgrade, replace, or supplement the mitigation* (if it fails in function or structure). Specific contingency mitigation and a commitment of funding and schedule must be described. The plan must also include mitigation for the time lag in case a mitigation technique fails in function. The commitment must be legally binding such as with a bond or contract;
- a *study plan, which should include specific experimental goals and objectives* and clear success criteria that will be used to measure success of the mitigation and further the development or acceptance of the concept. The study plan should include specific performance standards, contingencies, experimental process and schedule to address expectations and actions to address failure;
- a *commitment to a monitoring plan*, including baseline information, reporting and peer critique of findings; and
- a *closure to the experiment*. At the conclusion of the study, the mitigation should either be accepted or not accepted as adequate by regulatory agencies agreeing to the experimental application. The contingency plan is activated for projects that do not have complete and accepted mitigation.

Before a technique is accepted as a standard method and specific design details are provided, a history of monitoring experimental installations is needed. In the meantime, details of current design principles of some experimental technique are provided in these guidelines. Design and mitigation recommendations are likely to change as new observations and data become available.

Integrating Mitigation into Bank-Protection Projects

As described earlier, compensatory mitigation is required when a project causes damage or risks causing damage to or loss of habitat or the opportunity for habitat to form is impaired. Compensatory mitigation involves the restoration, repair or replacement of habitat that has been damaged. It also is called for when the opportunity for habitat to be created is lost due to project activities.

Compensatory Mitigation Target

A compensatory mitigation target is the condition or measurable level of performance that must be achieved as a result of doing the mitigation. Such targets must be provided for projects that call for compensatory mitigation. Compensatory mitigation targets are to be set and implemented only after the avoidance and minimization mitigation approaches have been exhausted.

A compensatory mitigation target is the condition or measurable level of performance that must be achieved as a result of doing the mitigation.

There are four general targets for compensatory mitigation:

1. improvement of factors within the watershed that limit fish and/or wildlife production,
2. restoration of properly functioning habitat,
3. replication of current natural conditions, or
4. restoration or replacement of preproject conditions.

The sequence of the list reflects a decreasing extent of analysis and needed information.

Mitigation targets vary in scope from an entire watershed down to specific site conditions. Mitigation targets might also vary depending upon the objectives and authorities of the agencies that issue the permits to work in stream channels. The ability to take action based on concepts like channel processes, lost opportunity and potential productive capacity differ depending on the mitigation target applied to a project.



Improvement of limiting Factors

The Revised Code of Washington (RCW 75.46) defines limiting factors as “conditions that limit the ability of habitat to fully sustain populations of salmon.” Taking steps to reduce the effects those limiting factors have on habitat can increase the functionality and restore the productivity of a reach or basin. Considering limiting factors in mitigation design allows innovative mitigation that can affect productive capacity. Enhancement of limiting factors would increase the function that is limiting to productive capacity of a reach or a basin.

The Washington State Conservation Commission is doing formal analyses of limiting factors for salmon in Washington watersheds.² Completed analyses are available for a small number of watersheds. Limiting factors are often identified as a suite of factors rather than a single factor that limits productivity. Limiting-factor analyses are key to a successful mitigation design but not all that is needed. Limiting factors might change over time as conditions change and new information is gained.

There are several ways limiting factors might be applied to mitigation planning, including directing mitigation at the limiting factor regardless of the type of habitat affected by a project. For example, impacted spawning habitat might be compensated through buying water rights that will result in lower water temperatures. Alternatively, mitigation for impacts to limiting factors might be at a ratio greater than what is applied to factors that are not limiting since the risk to productive capacity is greater. Limiting factors tends to focus on a single genus or species instead of broader ecological values and multiple species. Even if just one species or species habitat is targeted, impacts to other species should be addressed as well. Mitigation that supports natural channel processes is by far preferable to mitigation that forces a stream channel into an unnatural pattern or creates artificial conditions.

The implications of off-site mitigation should also be understood. There is some risk of not mitigating for specific habitat lost until eventually that habitat becomes a limiting factor itself. Any compensatory mitigation done off-site has the likelihood of impacting habitat and must also be part of the project mitigation requirement.

This type of mitigation might be off-site and/or out-of-kind. This target works best in the following circumstances, adopted from the Alternative Mitigation Policy Guidance - Interagency Implementation Agreement (AMPG-IIA):

- limiting factors are understood either by formal or informal analyses,
- greater limiting or critical functions can be achieved off-site than is possible on-site,
- adversely affected functions are of low quality,
- there are no reasonable on-site opportunities,
- on-site opportunities do not have a high likelihood of success due to development pressures or adjacent impacts to the compensatory mitigation area, or
- off-site enhancement and restoration opportunities have a higher likelihood of success than on-site options.

Mitigating limiting factors requires a way of valuing one habitat type relative to another: What is the value (habitat value as well as cost) of a unit of nonlimiting habitat (e.g., spawning habitat) compared to the value of a unit of limiting habitat (e.g., water temperature) that is built as mitigation? Providing additional rearing habitat that currently limits productive capacity might compensate impacted spawning habitat. It also requires specific methods of quantifying existing habitat. Both of these issues are explained later in this chapter; in the section, *Quantifying Mitigation Needs*.

Properly Functioning Habitat

An analysis of properly functioning habitat focuses on the specific reach or site affected by a project. This concept is included in these guidelines because the National Marine Fisheries Service suggests using a similar process in its assessment of whether a project will “take” (contribute to elimination of) an endangered species.³ The process evaluates each component of the existing habitat compared to numerical standards that define the habitat as functional or nonfunctional. It is expected that a project will not have an impact if it doesn’t move the characteristic out of the preferred range. A project design is said to be preferred when it moves a characteristic into the desired range. For example, a project might not be allowed that would increase the fine-sediment composition of a spawning bed to a level greater than the defined deleterious threshold.



Mitigation might be done by increasing the function or quantity of a habitat. In effect, lost habitat is mitigated by replacing it, resulting in properly functioning habitat. Where water quality does not comply with properly functioning habitat standards, water-quality improvements might be made as mitigation for loss of spawning habitat.

Just as in the limiting-factors analysis, this process implies understanding a relative value of one habitat type in relation to another; providing additional rearing habitat where it is not functioning properly might compensate impacted spawning habitat. It also requires specific methods of quantifying existing habitat.

This type of mitigation is out-of-kind and may be either on-site or off-site mitigation. This target might be appropriate in the following circumstances adopted from the AMPG-IIA:

- when the resources adversely affected provide minimal desirable function, and they are neither limiting for a special species nor determined limiting within the watershed (Special species are identified in the AMPG-IIA as “plants or animals listed by the state or federal government as threatened or endangered and those that are candidates for listing. It also includes the priority habitats and species designated by the Washington Department of Fish and Wildlife and those species designated as species of local concern under the [Washington State] Growth Management Act.”); or
- when out-of-kind functions are critical or limiting within the watershed and provide a net gain for the resources of the watershed.

As discussed with limiting factors, mitigating functional habitat require methods for quantifying habitat and a way of valuing one habitat type in relation to another. Both of these issues are explained in this chapter under the section of this chapter titled *Quantifying Mitigation Needs*.

Replication of Current Natural Conditions

This is the process of copying at the project site the channel of a nearby undisturbed reach. A reach is identified with the same or similar hydrologic, sediment, geologic and climate conditions and it is replicated at the project site.

“Undisturbed” habitat is assumed to be noneroding, which may not be possible at the project site. If the entire reach is evolving to a changed hydrology, erosion might be the natural condition. It’s important to capture channel function when characterizing a representative reach. To fully characterize the representative site, physical features that are characterized and replicated might include rates of channel migration and rate of recruitment of sediment and debris.

This target is useful where land uses at the project site have obliterated the natural channel characteristics or where there is not information regarding condition of the habitat or habitat limiting factors.

This type of mitigation is on-site and out-of-kind. This process might be appropriate in the following circumstances adopted from the AMPG-IIA:

- when resources adversely affected provide minimal desirable function and are not considered limiting, or
- when out-of-kind functions are critical or limiting within the watershed and provide a net gain for the resources of the watershed.

Restoration or Replacement to Preproject Conditions

A traditional approach to mitigation is to restore a habitat feature of the same type that is lost as a project impact. This approach is commonly used because it requires the least amount of information for application. There is no need to understand the habitat loss of a project; the same physical features are simply mapped and replicated in the mitigation.

Exact duplicate features are not necessarily created. Restored features should include substrate, channel shape, unique features, and depth and flow of water. They must be mitigated to be naturally self-maintaining and/or self-generating as the initial habitat was. The intent is to restore or replace *functions* rather than replacing specific features.

This concept does not account for potential productive capacity or future conditions by consideration of either limiting factors or functional habitat. It tends to perpetuate existing degraded habitat.



Such an approach is, however, useful for simple and small-scale projects or where there is not information regarding condition of the habitat or habitat limiting factors. No information is needed other than characteristics of the preproject channel that can be restored at the site within the project. If not applied appropriately, this concept leads to static constructed habitat with little regard to the natural channel function. If applied appropriately, it is applicable in pristine habitat. Application of this at sites that were affected directly or indirectly by development or land use is usually not appropriate since it only preserves a deteriorated condition.

This type of mitigation is on-site and in-kind. This target applies but is not limited to the following circumstances adopted from the AMPG-IIA:

- the on-site location is critical for protecting or replacing important location-dependent functions that are lost due to project impacts;
- the location or natural conditions on a site play a key role in larger watershed functions and health, or they are important to a special species;
- the on-site location has a high likelihood of success and will not be influenced by adjacent development pressures;
- adversely affected functions are limiting within the watershed and are vital for replacement;
- adversely affected functions are critical to the continued health of the watershed or of a special species; or
- adversely affected functions are of high quality and should be replaced.

On-site and in-kind mitigation may be required in other circumstances as determined by site-specific needs or at the discretion of the permitting agencies.

Quantifying Mitigation Needs

Several of the targets described in these guidelines require methods of assessing the quality and quantity of existing habitat at a site, habitat and channel characteristics of a representative reach and monitoring constructed habitat. The methods developed under the Timber-Fish-Wildlife (TFW) management system in Washington State for ambient monitoring are probably among the most recent and most quantifiable. The TFW Monitoring Program at

Northwest Indian Fisheries Commission and the Washington State Department of Natural Resources Forest Practice Division publishes methods manuals.⁴ The AMPG-IIA recommends “*project impacts and mitigation success should be measured with the Habitat Evaluation Procedure, the Washington State Wetland Functional Assessment Method, photographic documentation, or other methods acceptable to the permitting agencies.*” The physical surveys the Washington Department of Fish and Wildlife uses for habitat assessment above fish-barrier culverts may be acceptable as a minimal approach for smaller projects. That method is described in the agency’s *Fish Barrier Assessment and Prioritization Manual*.⁵ Specific habitat-monitoring protocols are described and evaluated in *Inventory and Monitoring of Salmon Habitat in the Pacific Northwest - Directory and Synthesis of Protocols for Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia*, also published by the Washington Department of Fish and Wildlife.¹

None of these methods identify concepts such as future conditions, lost opportunities and habitat diversity. For bank-protection projects, habitat-assessment methods should identify debris and sediment sources, flood refuge, and habitat complexity and diversity.

There are recognized standard methods for assessing biological diversity. Biological diversity is the number of species in an area and includes a measure of the variety of species in a community and the relative abundance of each species. These methods might be modified to provide mitigation evaluation tools but will not provide the right information for habitat assessment for the purpose of mitigation design.

Several of the mitigation targets described in these guidelines require a way of valuing one habitat type relative to another. What is the value (habitat value as well as cost) of a unit of habitat that does not limit productive capacity compared to the value of a unit of limiting habitat that is built as mitigation? For instance providing additional rearing habitat where productive capacity is currently limited might compensate impacted spawning habitat.



One way to assign mitigation a financial value is to state it in terms of avoided costs. In other words, what actions were avoided by doing the mitigation, and what would those avoided actions have cost? The estimated cost of mitigating for the specific habitat lost could be applied to another habitat type. For example, the cost of replacing spawning habitat could be estimated and then that amount could be applied to the acquisition of water rights if that action were appropriate for either limiting factor or functional habitat mitigation.

EMERGENCY BANK PROTECTION

There are two types of emergency bank-protection projects. The first is the flood fight—actions taken during a flood to address the immediate threat of erosion during a flood. The second activity is bank repair after the flood—often with the risk of additional floods in the near future.

Most emergencies involving bank failure along streams and rivers occur during floods, when water levels are high and erosion occurs. Inundation and poor weather reduce visibility and complicate access for people and equipment. When a stream or riverbank is failing during such conditions, the key questions that arise are:

- Are immediate bank-protection actions during the flood prudent, necessary and effective?
- What bank-protection measure will work best to solve the emergency problem and can be implemented during high water conditions, safely, without high cost and impacts to the site?
- What materials are immediately available for bank-protection work?
- What are the best ways to physically implement the bank-protection measures during high water and poor weather conditions?
- What permits are required to do bank-stabilization work, and can they be expedited?

What Constitutes an Emergency?

Federal, state and local regulatory and resource agencies have differing jurisdictions and regulations for emergency bank stabilization during floods. The differing definitions and authorities can be especially confusing while in the throes of a flood fight.

Most agencies require approval of activities prior to constructing emergency bank protection. Washington State law (RCW 75.20.100(5)) regarding Hydraulic Project Approvals (HPAs) issued by Washington Department of Fish and Wildlife has specific language defining emergency situations and response to them:

“(a) In case of an emergency arising from weather or stream flow conditions or other natural conditions, the department, through its authorized representatives, shall issue immediately, upon request, oral approval for removing any obstructions, repairing existing structures, restoring stream banks, or to protect property threatened by the stream or a change in the stream flow without the necessity of obtaining a written approval prior to commencing work. Conditions of an oral approval to protect fish life shall be established by the department and reduced to writing within thirty days and complied with as provided for in this section. Oral approval shall be granted immediately, upon request, for a stream crossing during an emergency situation.

(b) For purposes of this section and RCW 75.20.103, “emergency” means an immediate threat to life, the public, property, or of environmental degradation.

(c) The department or the county legislative authority may declare and continue an emergency when one or more of the criteria under (b) of this subsection are met. The county legislative authority shall immediately notify the department if it declares an emergency under this subsection.

The Washington Department of Fish and Wildlife has adopted specific procedures to deal with emergency HPAs:

Verbal request. Determine if an emergency per 75.20.100(5) exists; if it does, make site visit if possible and issue a HPA on site, otherwise gather details over phone, and give verbal conditions for limited amount of work that are specifically necessary to address the emergency; put verbal conditions into written HPA within 30 days for record; if no, determine if the situation meets requirements for an expedited HPA per 75.20.100(3). If yes, require written application (may receive at site visit) and issue HPA within 15 days.



Written request - Determine if it meets emergency or expedited requirements. If it meets emergency requirements, contact person, make site visit, and issue an HPA on site; if the request meets expedited HPA requirements, visit site and issue within 15 days.

Designing and Installing Bank Protection During Emergency Conditions

Design and installation of bank protection during high water is difficult. Emergency installation is more costly than during low-water conditions because access is more difficult, timing is more immediate, there are fewer options for treatment and use of materials is generally less effective. Emergency situations can also cause an increased cost for mitigation since damage from an emergency project is usually greater, and equipment re-mobilization is required for post-project mitigation. Project impacts for emergency work have to be mitigated just as they are for projects with normal timing. It is, therefore, important to minimize impacts during project installation because it is likely that mitigation will already be more difficult and costly. Under emergency scenarios, the tendency is to act to protect a bank regardless of the existing trees and other vegetation. Keep in mind, however, that these same trees and vegetation may naturally provide bank protection once the emergency subsides. Such vegetation also reduces the future need for bank stabilization. When it comes to habitat, preserving existing vegetation also assists in mitigation efforts because it provides important riparian habitat. Therefore, vegetation should be protected even if it offers no immediate stabilization value.

Project impacts for emergency work have to be mitigated just as they are for projects with normal timing.

Since many bank-instability problems show initial evidence during low flow, it's a good idea to develop a contingency plan prior to the advent of an emergency.

Safety of those installing bank stabilization is another important aspect of emergency protection. Working adjacent to flood waters is dangerous. Deep water; fast, unpredictable currents; rapidly rising water levels; floating (or subsurface) debris and woody material all contribute to the extreme hazard.

Emergency Bank-Protection Techniques

Floods tend to impose their own set of complexities and limitations on bank-protection projects:

- Placement, anchoring and constructability during high flows;
- visibility below the water surface is obscured;
- equipment access may be limited;
- the site can't be drained; and
- safety issues are very real but unpredictable.

A typical bank-protection request during a flood is to dump large rock from the top of a bank. Such actions get in the way of other immediate and future creative solutions such as composite banks or vegetated revetment unless they are permitted strictly as temporary emergency work, with the requirement to remove and replace the work with more appropriate measures at the next appropriate work window. Deep water doesn't allow visibility below the water surface. Thus, when working in deep water, it is difficult to know where the dumped rock landed, how it is oriented and what its effect is. Another problem that arises in taking this type of emergency action is that, often, more rock is used than is necessary. To complicate installation, saturated bank conditions make heavy equipment access difficult, if not impossible.

Techniques suitable for emergency conditions are discussed in Chapter 5 and in the descriptions of specific techniques in Chapter 6, *Techniques*. Those featured include exposed and buried groins, anchor points and avulsion-prevention techniques in the floodplain, such as placement of debris or roughness. Dumped rock is also feasible but should be considered only after all other options have been ruled out, including those that would disturb the riparian zone less or require less rock and/or are easier to modify during the project follow-up. Placing bank-protection measures that immediately fail can exacerbate the problem, increasing the extent or rate of additional bank failure.



Follow-Up Work After Installation of Emergency Bank Protection

Some level of follow-up work is after required after installation of emergency bank protection and after floodwaters have receded. Follow-up can range from simple (such as re-seeding of disturbed areas) to extensive (removing dumped rock and replacing it with a more suitable and environmentally acceptable alternative). Every project built under an emergency HPA should be studied after the flood has receded, and a follow-up report should be developed by the applicant and interested agencies. The following are questions to ask following emergency bank-protection actions:

- Is the bank-protection technique consistent with concepts described in these guidelines?
- Are fish and wildlife habitat impacts fully mitigated? What is necessary for full mitigation?
- What site cleanup is needed? Are there unused materials left around the site?
- What should be done in terms of revegetation of disturbed ground, either by seeding or planting of shrubs and trees?
- Should the bank-protection measure be adjusted to function better or reduce habitat impacts, for example, to change the shape and extent of placed rock?
- Are the transitions of the treatment into adjacent stable banks adequately installed?
- Can habitat and vegetation be added to the treatment to reduce any adverse environmental impacts?
- Overall, will the bank protection continue to function in the future, or should it be adjusted, redone or removed? If, after-the-fact design analyses were undertaken, would the bank protection meet the stabilization objectives and design criteria?

MAINTENANCE, ADAPTIVE MANAGEMENT AND MONITORING

Streambank stabilization requires maintenance. Because streams are dynamic and many bank-protection measures include living plants and biodegradable material, the potential is high for stabilization measures to change in some way over time and through flood events. The only way that such changes can be observed is through a monitoring program (see Appendix J, *Monitoring*).

Streambank-protection measures do not function in a static setting. Typical changes might include: migrating meander forms; adjustments to water and/or sediment supply from upstream; and impacts to vegetation survival from on-site land use. These changes are gradual and sometimes imperceptible to the casual observer, until a high-flow event occurs, when change may be sudden or even catastrophic. To ensure that bank-protection measures do not fail, it is important to establish a formal monitoring program.

Monitoring of bank-protection measures typically involves an intensive period of evaluation during the first few years after a project has been installed. After that, a less intensive evaluation is acceptable. Monitoring a project site two or more times during the first few years, when vegetation is re-establishing and the protection measures are less tested, is especially important where the bank-protection measures rely heavily on plants to provide long-term stabilization. After vegetation has been established, monitoring once a year, or every other year is adequate.

The level of cost and risk associated with a project dictates the appropriate level of monitoring. Costly, high-risk projects require a detailed monitoring plan that identifies what should be measured, and how and when it should be measured. A small-scale project might simply involve developing a photographic record from one or more established photo points. A monitoring plan might include: taking photos, measuring bank and channel cross sections, measuring plant densities and species composition, assessing fish habitat, and estimating fish use. For a more detailed discussion on monitoring, see Appendix J.

If monitoring indicates that a bank-protection measure is not meeting design criteria, then adjustments can be made to ensure the continued long-term function of the treatment. Such maintenance is called “adaptive management,” because it identifies over time what changes might have occurred and what needs to be done. Adaptive management for streambanks involves maintaining appropriate vegetation, ensuring that toe protection remains intact and watching transitions from treatment to non-treatment along a bank to make sure they do not weaken and become prone to failure. It may involve planting trees, or pruning trees that have become too big. Severe pruning and tree felling to prevent tree throw



should only be done where there is a limited riparian corridor; no opportunity for the corridor to be widened and a high risk of further erosion. Adaptive management may involve installing a different kind of bank protection should the original treatment fail. For example, if an attempt to rely solely on vegetation did not work, then a treatment with more rigid materials might be required.

For descriptions and evaluations of specific habitat monitoring protocols, refer to Johnson, et al.¹

CONCLUSION

There may be significant consequence, productive or destructive, to any treatment that may be applied to rivers and streams. Determining those consequences, weighing them against risks to habitat and safety of people and property is crucial in selecting a treatment that is most effective. In Chapter 5, we'll explore how to identify and select the most appropriate treatment(s) to meet the particular circumstances present.

REFERENCES

- 1 Johnson, D. H., N. Pittman, E. Wilder, J. A. Silver, R. W. Plotnikoff, B. C. Mason, K. K. Jones, P. Roger, T. A. O'Neil and C. Barrett. 2001. Inventory and Monitoring of Salmon Habitat in the Pacific Northwest - Directory and Synthesis of Protocols for Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia. Washington Department of Fish and Wildlife, Olympia, WA.
- 2 Limiting factors analyses cited as having been published by the Washington State Conservation Commission are available from that agency online at www.scc.wa.gov/resources/library or by mail at the Washington State Conservation Commission, P.O. Box 47721, Olympia, WA 98504-7721.
- 3 Federal Register, July 10, 2000. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, 50 CFR Part 223. Endangered and Threatened Species; Salmon and Steelhead; Final Rules.
- 4 Publications cited as having been published by the Northwest Indian Fisheries Commission are available from that agency online at www.nwifc.wa.gov/TFW or by mail at Northwest Indian Fisheries Commission, 6730 Martin Way E. Olympia, WA 98512.
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